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A Feather in Amber from the Upper Cretaceous of New Jersey[1]

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ABSTRACT

A feather 7.5 mm long is reported here in amber from the lower part of the Raritan Formation (Turonian, ca. 90–94 million years old [myo]), of central New Jersey. It is probably a semiplume, and is as yet unassigned to any group of birds. The specimen represents the second record of a feather in Cretaceous amber, and, like the first, is of interest because of the intricately preserved detail and the phylogenetic significance of Cretaceous birds. This is the oldest record of a bird from a terrestrial deposit in North America, and presumably the oldest record of a terrestrial bird. A brief review of fossil feathers is given, including those in amber.

THE AMBER

Excavations are being made by the American Museum of Natural History of amber, or fossilized tree resin, from an unexpectedly rich deposit from the Raritan-Magothy Formation (Turonian) of central New Jersey. Within this wealth of new material is a small menagerie of various families of arthropod inclusions, which will be treated in separate papers. While screening the amber for inclusions, one piece was found by D.G. to contain an almost complete, beautifully preserved small feather. As is reviewed below, feathers are exceptionally rare in any amber, even the abundant Tertiary ambers. Given the relatively poor fossil record and the phylogenetic importance of Mesozoic birds (see, e.g., Cracraft, 1986), any report of a Mesozoic feather would be of particular interest.

The amber specimen derives from a very localized, concentrated deposit, occurring in layers 15 cm to 1 m thick of carbonized, highly compressed, mixed fragments of fossil

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wood, conifer needles, and stems of Equisetales (referred to here collectively as lignite). The lignite is intercalated among alternating layers of similar thickness of fine sand and clay, but lies atop a floor of thick, dense clay at least 7 m deep. This is the South Amboy Fire Clay, dated palynologically by Christopher (1979) as Turonian. The amber itself occurs in the lignite in small droplet and stream shapes from 2–3 mm in diameter, to large pieces 10–15 cm long and 8–12 cm wide. The material can be a very transparent yellow, but is often turbid and cloudy, even milky. Microscopic bubbles, particulate debris, and particles apparently from the bark and leaf litter cause the opaqueness of some of this amber. Grimaldi et al. (1989) treated the paleontology of New Jersey fossil resins. The botanical origin of this Cretaceous amber apparently lies with the Araucariaceae, based on the structure of large pieces of carbonized wood found with the amber as well as on the chemistry of the amber. The site of the excavations is undoubtedly a lagoonal or deltaic deposit, with the lignite and its amber representing stranded, redeposited material. Origin of the feather is almost certainly terrestrial, since the amber appeared to have been produced in the araucarian forest. A detailed description of the physical properties of the amber, its stratigraphic occurrence, and paleoecological reconstruction of the site will be given elsewhere. The site is located close to and roughly contemporaneous with amber site numbers 4 and 5 in Grimaldi et al. (1989: map fig. 4).

Acknowledgments

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THE FEATHER

The feather is in a piece of amber that originally was 2.5 × 4 cm. Concentric rings could be seen on one end, indicating numerous flows of resin over the original stream of resin, which is typical of the larger, oblong pieces from this formation. The portion with the feather split at the interface of two flow lines, revealing a small feather lying just under the smooth, concave surface of the outer flow. The rachis was mostly embedded in the amber, but partly exposed, so a thin coating of synthetic resin (Permount) was applied to the entire surface of the feather to prevent oxidative damage. All barbs were embedded just under the surface of the amber. The refractive index of Permount is very similar to that of Canada Balsam and amber, but is faster drying than Balsam. The feather lies in a layer that is slightly cloudy; the inner flow is considerably more turbid. The feather apparently wafted onto a partially hardened resin flow, but was stuck fast and almost entirely immersed into fresher resin that flowed over it. The layer with the feather cracked near the middle when the pieces were separated from each other, but was then "glued" back together using Permount.

Length of the feather is 7.57 mm, as measured along the curvature of the rachis, or shaft. Barbs near the base are approximately 1.5 mm long, and 0.8–0.90 mm near the tip. Rachis thickness is 0.24 mm; the barbs on each side number slightly over 200. A small segment at the base of each barb is slightly flattened and spindle-shaped. Since the feather lies close to a glassy surface, it was possible to examine details of the barbs at 160× and 400× magnifications using a Zeiss compound microscope and phase-contrast objectives. No barbules or hooklets are present. The rachis is broken at the base, so the length of the quill, or calamus, is unknown. Coloration is unapparent. Based on these features, it seems most apparent that the feather is a *semiplume,* not a contour, down, primary, or secondary flight feather. Typical semiplumes have a prominent shaft and a loose, plumulaceous web, and lack the hooked structures (or hamuli) seen in the distal portions of contour feathers. They provide insulation, flexibility near the bases of appendages, and buoyancy in water birds (Van Tyne and Berger, 1976). Semiplumes occur at the margins of feather tracts and apteria and are usually overlain by the contour feathers. Downy feathers are also usually concealed beneath

contour feathers, and are small and soft, with a very short rachis.

The specimen, AMNH-NJ-1, is deposited in the amber fossil collection, Department of Entomology, AMNH. Collected by Paul D. Borodin, Gerard R. Case, and James J. Leggett.

DISCUSSION

The Mesozoic is the time of origin and early diversification of the birds. *Archaeopteryx,* from the upper Jurassic, is largely recognizable as a bird on the basis of well-preserved impressions of contour feathers. A wealth of exciting new taxa of Cretaceous birds has only recently come to light, as reported by Perle et al. (1993), Elzanowski (1976, 1983), Hou and Liu (1984), Kurochikin (1982), Sanz et al. (1988), Lacasa (1989, 1991), Sereno and Rao (1992), Chiappe (1993), and others. Taxa described previous to these were analyzed phylogenetically and reviewed by Cracraft (1986). The fossil record of their feathers, however, is considerably more scant. Since Martins-Neto and Kellner (1988) gave a rather detailed review of Mesozoic bird feathers (in Portuguese), only a brief summary of the particularly interesting Cretaceous feathers is given here.

Cretaceous

1. Portions of several feathers, surely from a single individual (in one piece of amber), from the Lower Cretaceous of Lebanon (Schlee, 1973). This amber is the oldest in the world with insect inclusions (Neocomian, ca. 125 mya [Schlee and Dietrich, 1970]). Schlee studied the detailed morphology of these feathers, using 500–900× magnification under compound microscopy. Various conclusions were made on the area of the body where the feathers were located and how they functioned in flight, based on the microscopic measurements. Drawings, analyses, and color photographs of the specimen are in Schlee and Glöckner (1978: 63–64, pl. 3). This is the oldest record of a feather in amber; the New Jersey amber specimen is the second oldest, about 30 million years younger.

2. Several feathers in fine-grained limestone from the Lower Cretaceous of Montsech, Spain (Gómez, 1986; Lacasa, 1991). There are approximately of the same age as the Lebanese amber (Neocomian) and are better preserved than the Santana limestone feather (see below). Barbs are easily distinguished on an apparent semiplume feather.

3. A trailing primary or secondary flight feather 64 mm long in fine-grained limestone from the Santana Formation (Aptian-Albian, ca. 120 myo) of Brazil (Martins-Neto and Kellner, 1988). A full-page color photograph of this specimen is in Maisey (1991). It has an asymmetrical vane, but preservation is not fine enough to discern barbules, and the barbs on the proximal half have been scraped away, presumably by the quarry workers. A down feather is also known from this deposit (A. Kellner, personal commun.).

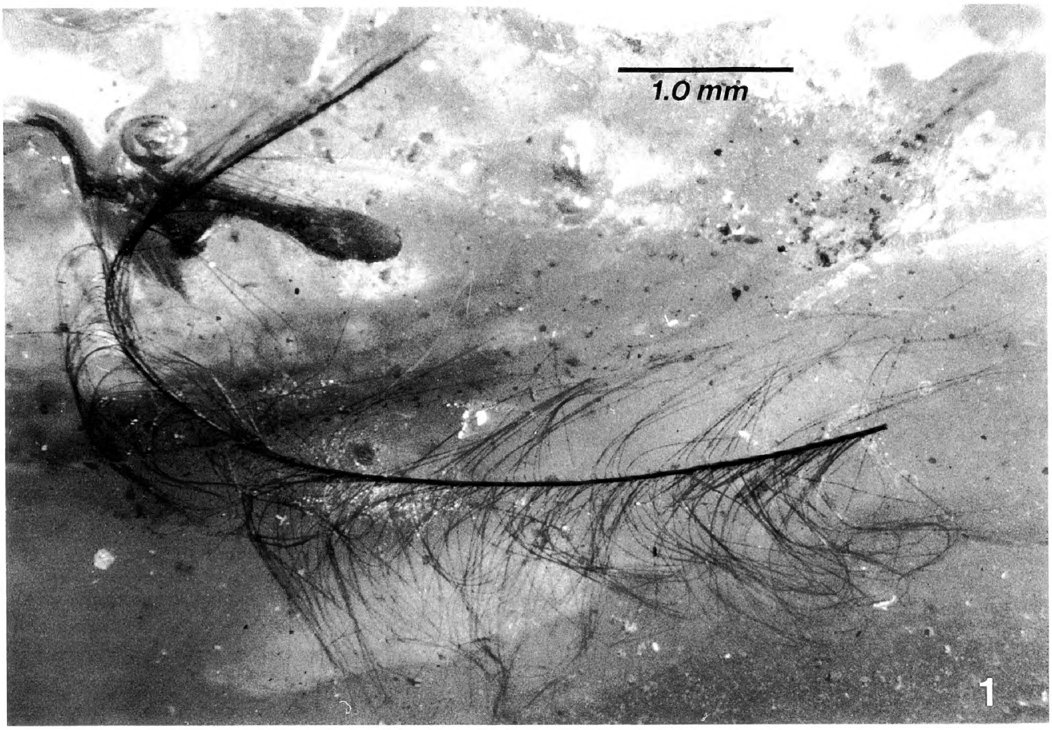
4. Several feathers have been reported from fine-grained siltstone from the lower Cretaceous of Koonwarra, Australia (Talent et al., 1966; Waldman, 1970; Molnar, 1980). They are small contour feathers (ca. 15–20 mm length) with a stout calamus. Other lower Cretaceous feathers are reported by Kurochikin (1985).

5. Two other feathers exist in Upper Cretaceous amber, both as yet unpublished. One comprises the distal portions of five barbs in Santonian amber from the Taneichi Formation of Kuji, Japan. The barbs have long, distantly spaced barbules. The other feather, which we have not seen, is also in amber of Santonian age, from Alberta, Canada.

It is significant that the only pre-Coniacean fossils of birds from North America occur in marine sediments of the interior seaway, which are *Ichthyornis* and hesperornithiformes. The feather in New Jersey amber, thus, is the oldest terrestrial record of a bird in North America. No mineralized remains of bird or other vertebrate bones or teeth occur in the amber strata that were excavated by the AMNH. Bird remains are diverse, however, in the glauconitic sands of the Maastrichtian–lower Paleocene of New Jersey (Olson and Parris, 1987).

Tertiary

Compression fossils of bird feathers are more common in Tertiary sediments, and are



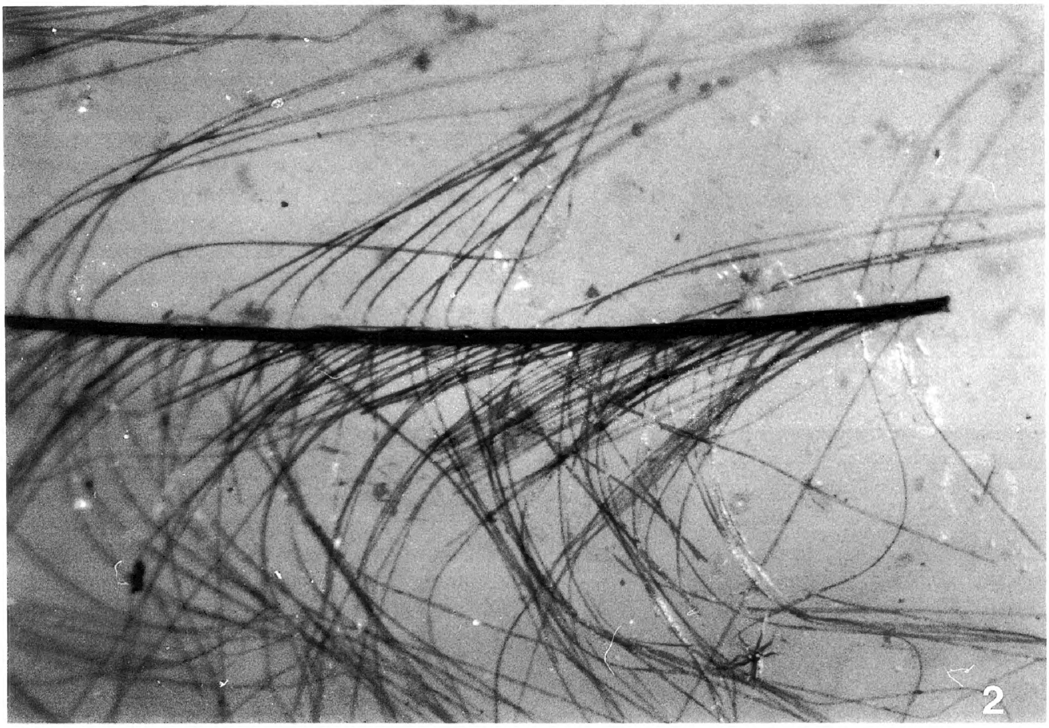


Fig. 1. Photo of entire feather specimen in New Jersey amber.

Fig. 2. Detail of rachis and barbs.

even found in some ambers. Bachofen-Echt (1949), for example, mentioned feathers of *Parus* (Paridae), *Picus* (Picidae), *Sitta* (Sittidae), and even a *Momotus* (Momotidae) from Baltic amber (ca. 40 myo). However, the fine structure of these specimens has never been carefully examined, so these generic identifications are probably not accurate. Color photographs of a beautiful 1 × 1.5 cm contour feather in Baltic amber is in Schlee (1990: 14–16, figs. 9–12), which shows details of barbs.

A number of unstudied specimens of primary and secondary feathers in Dominican amber (ca. 25 myo) reside in private and museum collections (including the AMNH). Poinar et al. (1985) reported on a portion of a feather in this amber, although at least six complete feathers exist in collections. One of the most beautiful specimens is a contour feather in the Smithsonian Institution's Dominican amber collection, which Poinar (1992) mentioned as deriving from a woodpecker (Picidae). That identification was based on the work of R. C. Laybourne, which was recently published (Laybourne et al., 1994). By studying the microscopic features of the plumulaceous barbules of contour feathers, they were able to assign the feather not only to the Picidae (woodpeckers), but close to the extant Antillean species, *Nesoctites micromegas* (Antillean Piculet). Fortunately, woodpecker feathers are distinctive for the shape of the villi on the basal cell of the barbules (and features of the nodes and internodes on the barbules distinguishes *N. micromegas* from other Caribbean picids).

Careful identification of amber fossil feathers depends on this sort of microscopic work, as also done by Durrer (1977), Brom and Visser (1989), Brom (1986; 1990), Durrer (1977), and Perremans et al. (1992). However, all of these studies concern ultrastructural features of the contour feathers. If diagnostic ultrastructural features are found for semiplume feathers, then a reliable identification of this Cretaceous amber feather, perhaps to subordinal level, may be possible.

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